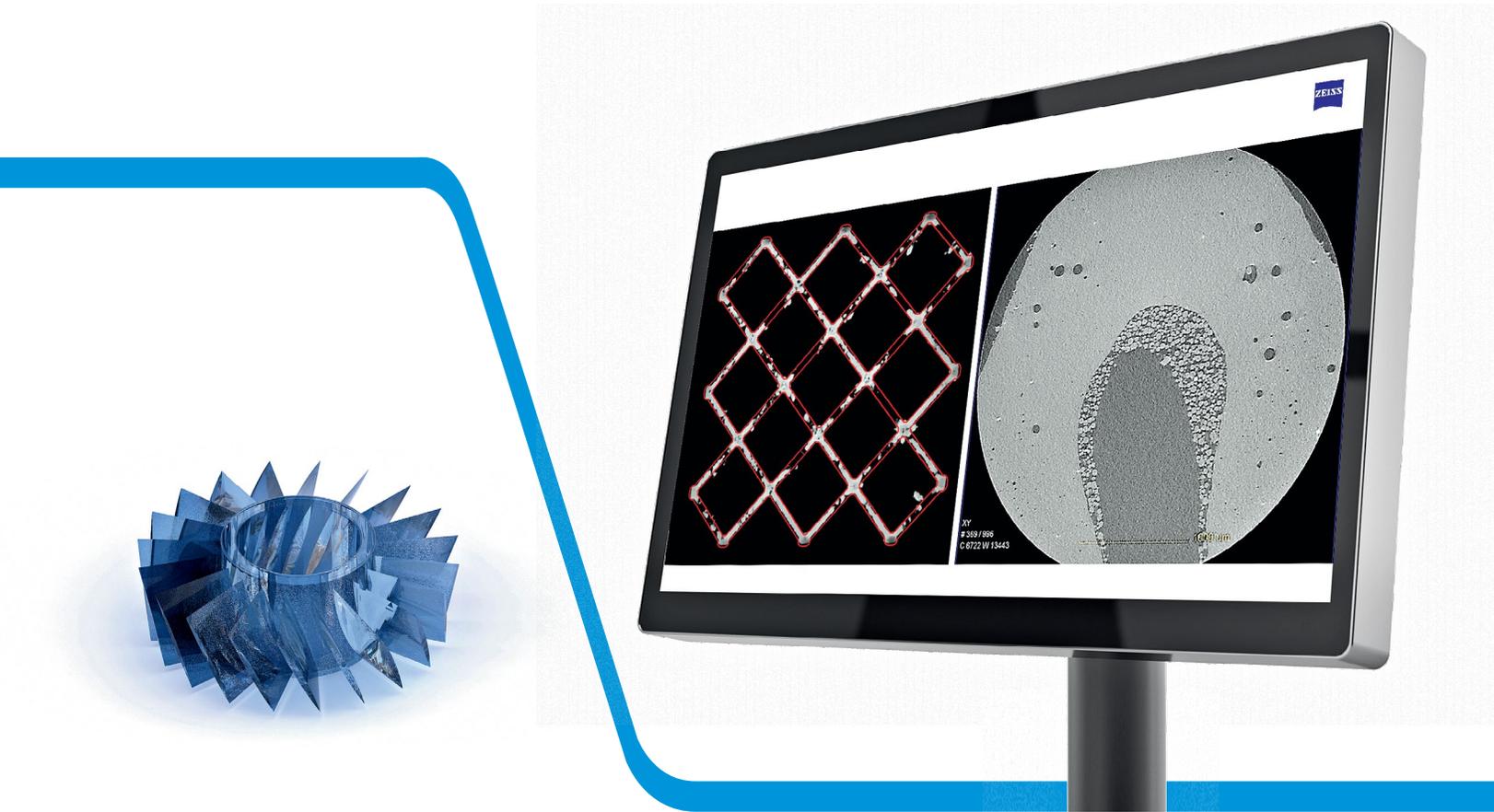


The Necessity of Defect and Inner Structure Inspection in Additive Manufacturing

ZEISS 3D ManuFACT



With conventional machining of metal component parts, the interior structures are often taken for granted as solid, leaving little room for doubt about the internal quality. With additive manufacturing (AM), however, the part isn't affected by welding or machining but rather by the quality of powder used in the material and how it spreads or layers during the build process. These concerns, as well as other factors that might cause voids or material impurity to form in the structure, are critical elements for inspection in the quality assurance process for AM.

A Comprehensive View of Completeness

As the 3D-printing process is increasingly used to produce safety-critical automotive, energy, aerospace and medical products and components, it is essential to detect these voids and inclusions in the finished part. To discover the presence of these kinds of defects in an AM part, manufacturers can utilize a light microscope (LM) or X-ray computed tomography (X-ray CT).

Using a light microscope, a close-up view on the build surfaces and features provides valuable insight into the quality of the part. It can identify possible flaws with the process parameters, allowing better understanding of the origination of micro-cracks and delaminations — a separation of layers that forms a mica-like structure of separate layers — that lead to a loss of mechanical toughness.

High-resolution X-ray CT can offer unique views into the unprecedented design freedom and complex inner structures made possible by AM. For example, with AM, the position and nature of defects may be random due to such factors as partially melted powder flying in the build chamber. X-ray CT can detect these 3D-printing defects with immersive structure views and analysis.

These metrology methods provide a comprehensive view of build completeness and significantly aid the optimization of the 3D-printing process. By supplying a full 3D density map of parts, these scanning methods can be viewed in cross-section in any direction and compared to the nominal CAD representation.

The Limitations of Surface Inspection

With traditional manufacturing processes that start from castings and forgings for a full-body method of manufacturing, a quality program may include a few radiographs at specific orientations.

With AM processes, however, the entire component is built in layers to create a whole part, increasing the risk that a layer is incomplete or has a gap.



There are several traditional non-destructive testing (NDT) methods, such as CMMs or 3D scanning, that are also being performed for the surface and external geometry of AM parts. However, when engineers have total freedom in designing a part with an AM process in mind, there is often internal complexity that can make the end result harder to inspect.

The AM process is susceptible to discontinuities that you do not find in castings and forgings. These quality concerns in AM can include:

- Excessive surface roughness
- Thin layer build
- Internal complexity

Gordon Styles, founder and president of Star Rapid, explains the importance of an internal view: "3D scanners only work for the exterior of the surface, not any hidden internal cavities that 3D printing enables. These cannot be conventionally measured and so their size and location must be inferred from the initial printing file.

This later consideration is crucial when machining features like thin-walled sections of conformal cooling channels. Take off too much metal and the part is ruined, or even worse, can fail in use. In critical applications, it is possible for special labs to perform high-resolution CT scanning to determine the dimensions of interior spaces."

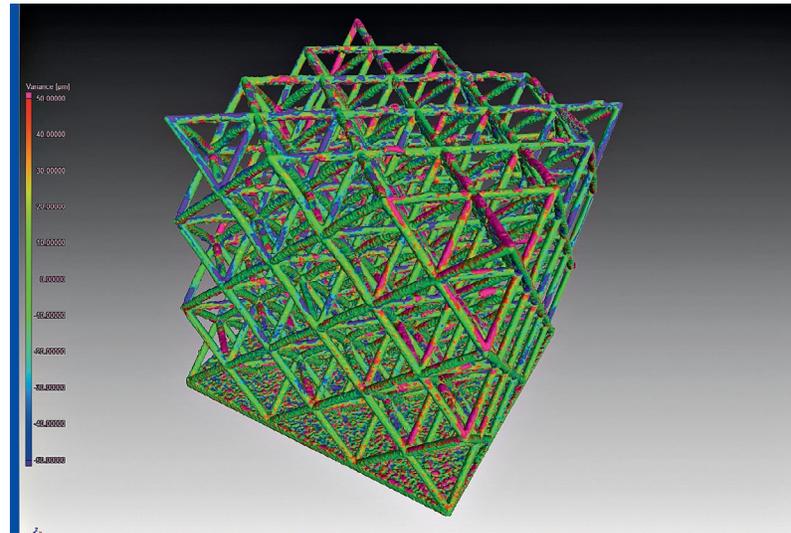
Internal Inspection — A Critical Step

There's been a sea change toward radiographic internal inspections in AM because this scanning technology enables the identification of cracks, porosities or inclusions inside parts. Defect analysis provides vital information about properties that can impact component quality and influence performance characteristics.

As Gregory James Weaver, director of operations at Vibrant Corp., says: "Knowing the limitations of these particular inspection methods, most AM manufacturers have turned to radiographic internal inspections to validate their parts. RT, especially digital RT (DR), and CT are currently the go-to inspections for many AM manufacturers. The inspections are used both to detect gross defects and to confirm internal geometry. These are decent inspections for these purposes, with CT being much more capable for geometry validation and DR being better at gross defect detection."

The internal structural integrity and dimensional aspects of additive manufactured parts can be assessed through LM and X-ray CT. The resulting data and measurement can identify:

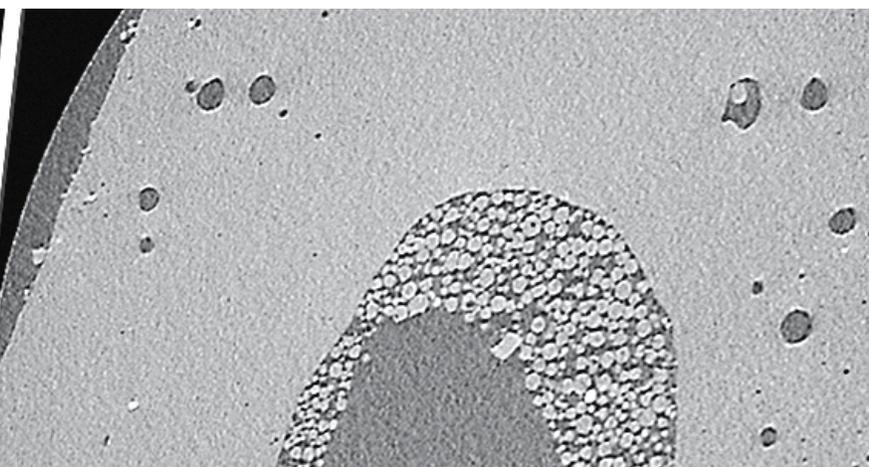
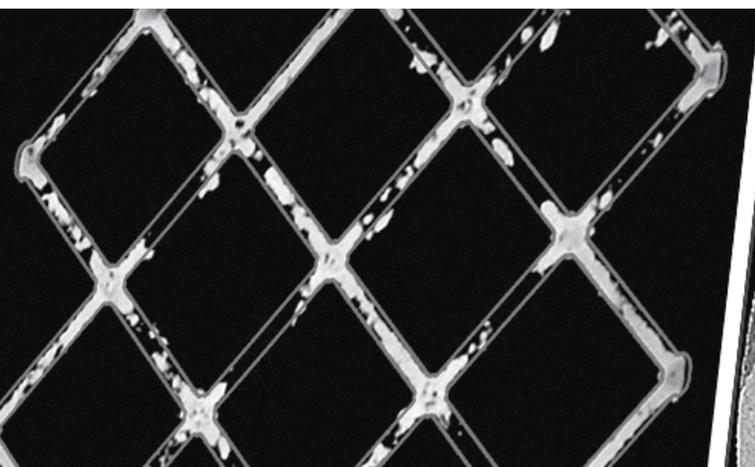
- Blocked channels from powder residues
- Porosity, contamination and cracking causing defects
- Wall thickness variation or warping resulting from CAD model deviation



"Unlike other types of 3D scanning and metrology, CT scanners can provide precise dimensions of internal and external structures," says Brian Albright, contributing editor to Digital Engineering. "The only other way to take those measurements is through destructive testing; you'd have to break the part or assembly to see inside."

Geometric information can be ascertained from the resulting data and be used to perform different analyses such as:

- Voids/inclusions analysis
- Part-to-CAD comparison
- Part-to-part comparison
- Wall thickness
- Reverse engineering



The ZEISS Solution for Internal Quality

ZEISS' 3D ManuFACT holistic integrated process for AM enables users to check the interior structure of components and identify defects or dimensional errors. Inspecting the quality of the build with LM or internal structures with high-resolution X-ray CT helps to determine the influence of process parameters and define potential paths to achieve optimal settings with quicker results.

Defect & Inner Structure Analysis Technologies



LM Products:

- The ZEISS Smartproof 5 is a high-resolution and high-speed optical profilometer for detailed surface analysis.
- The ZEISS Axio Observer is an inverted optical microscope for material analysis and detailed inspection of build patterns and cross sections.



X-Ray CT Products:

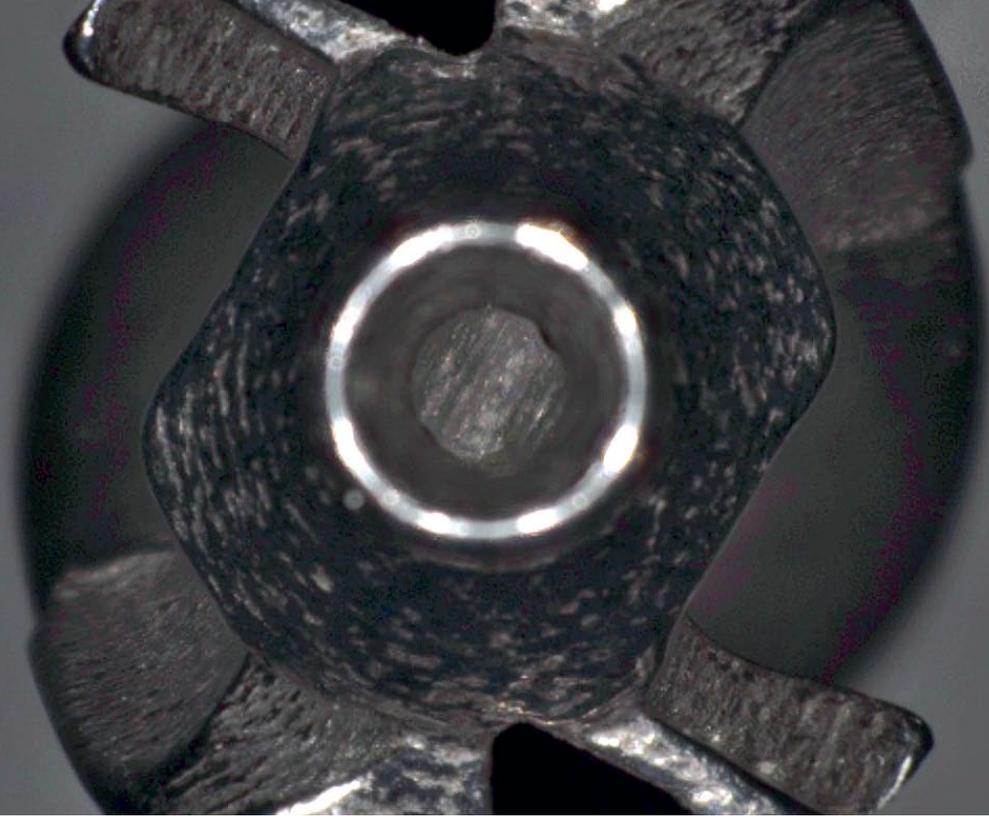
- The ZEISS Xradia Versa is a high-resolution X-ray CT that supports detailed analysis of powders, surfaces and structures with voxel size down to 70 nm.
- The ZEISS METROTOM is a high accuracy X-ray CT that supports dimensional verification and defect analysis of parts with complex internal and external structures.
- The ZEISS VoluMax is a high-speed X-ray CT that supports automated dimensional verification and defect detection of mass production quantities.

Metrology Services

Can't invest in industrial CT? Consider our metrology services and let our metrology experts perform the analysis for you.

ZEISS Metrology Services acts as an extension of your quality department to bring customized solutions to resolve your issues, get parts out the door and provide results you can trust. Non-destructive X-ray CT inspection includes:

- **Internal and External Analysis:** Through the use of X-rays, METROTOM technology allows our engineers to perform precise measurements on both external features and internal features without damaging the part — a process not possible with a standard probing system.
- **Assembly Analysis:** CT imaging allows the user to analyze infinitely thin cross sections of the sample in any orientation, visualizing form, fit and function of components in complicated assemblies.
- **Quantitative Analysis:** Used with the powerful Volume Graphics software, CT scans can be manipulated to investigate metrics like wall thickness, permeability, void size and location, and more.



Conclusion

3D printing has changed the rules of the manufacturing industry, and it demands a robust approach to quality inspection. ZEISS 3D ManuFACT is a powerful solution for businesses exploring this new paradigm. With NDT technologies such as light microscopes and X-ray computed tomography, you can be assured of full dimensional and tolerance quality control.

ZEISS 3D ManuFACT—From powder to performance.